ROLLER BEARING

BACKGROUND OF THE INVENTION

Field of the Invention

This invention relates to a roller bearing, and particularly to a roller bearing ~~in a bearing~~ for a spindle which is a portion of the constituent parts of various motors or the like and which exhibits ~~is~~ excellent ~~in~~ bearing characteristic and a ~~is~~ greatly mitigated susceptibility ~~in~~ fretting corrosion created by repeated shock and swing attributable to extraneous vibration as during conveyance.

Related Background Art

The industry related to electrical instruments is ~~high in the speed~~ a of technological innovation as compared with the other industrial fields. The available periods of particular types of machines are short, and ~~moreover,~~ new types of machines introducing ~~having introduced~~ new techniques (smaller electric power consumption, higher responsiveness, higher accuracy, compactness, etc.) are being developed one after another.

~~Now, the~~ The bearings for the spindles of various motors or the like have been required to provide ~~made~~ higher ~~in~~ speed capability with the development of the new types of machines as described above, and lower torque has come to be required of them for the purpose of smaller electric power consumption. In the roller bearings used for the

spindles according to the prior art, there have been adopted a lubricating portion ~~system~~ filled with grease, and a method of applying lubricating oil to the raceway surface or the like of the bearing and further enclosing ~~enclose~~ grease therein. At present, for the purpose of lower torque to accommodate ~~resulting from~~ the requirement for smaller electric power consumption as described above, an amount of grease is reduced ~~less~~, and as lubricating oil applied to the raceway surface or the like of the bearing, many lubricating oils of low dynamic viscosity (dynamic viscosity of 5 to 15 mm^2/s at 40°C) are used for rust prevention and ~~in the~~ low torque.

~~Now, the inland conveyance~~ The shipment of various motors often takes place on land, and they are transported in an ~~under~~ environment in which they are apt to be subjected to extraneous vibrations. By these extraneous vibrations, the bearings for the spindles suffer from axial vibration ~~excitation~~, or repeated circumferential swing depending on the way in which the instruments are placed.

When such axial vibration or circumferential swinging movement is repeated, a bearing for a spindle designed for ~~directed~~ to low torque may be subjected to ~~suffer from the possibility of creating~~ fretting corrosion on the raceway surfaces of the outer race and inner race thereof, and the contact surfaces of the rolling elements thereof. because the quantity of grease is small and ~~moreover~~ the strength of oil film is low in lubricating oil of

low dynamic viscosity.

The creation of fretting corrosion may result in an increase in the sound and vibration of the bearing and may also pose a serious hindrance to ~~problem in a~~ further improvement in required accuracy.

So, the present invention has been made in order to prevent the creation of fretting corrosion ~~which may be created~~ in a bearing for a spindle during the conveyance of various motors as noted above, and a principal ~~the~~ object thereof is to provide a fretting-resisting roller bearing which is not adversely affected in its characteristics and achieves a higher temperature and a higher speed as well as a longer life.

SUMMARY OF THE INVENTION

To achieve the above object, the roller bearing of the present invention is a roller bearing comprised of a plurality of rolling elements held between an inner race and an outer race with a cage interposed therebetween, characterized in that an ~~the~~ oil film of lubricating oil of which the dynamic viscosity at 40°C is 20 to 150 mm^2/s is formed on the raceway surfaces of the inner and outer races, the cage and the rolling elements and grease is enclosed.

The roller bearing of the present invention is heightened in the dynamic viscosity of the lubricating oil and the strength of the oil film with a view to

improve the fretting-resisting property during the conveyance of various motors.

Also, for example, the rolling elements are made of ceramics or a super-hard alloy of which the Vickers hardness is 1300 or greater, and the outer race and inner race are made of steel~~, and~~. Preferably, a material differing from that of the outer race and inner race is used as the material of the rolling elements and the hardness thereof is increased, whereby not only fretting corrosion can be suppressed by the prevention of the adhesion phenomenon between the members (the raceway surfaces of the outer and inner races and the rolling elements) and the decrease in Hertzian contact area due to the difference in Young's modulus, but also a good function is obtained even under use conditions of high temperature and high-speed rotation.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a graph showing the acceleration signal execution values of each embodiment and each comparative example.

Fig. 2 is a graph showing the rotation torques of each embodiment and each comparative example.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Some embodiments of the fretting-resisting roller bearing of the present invention will

hereinafter be described in detail.

The fretting-resisting roller bearing of the present invention is a roller bearing comprised of a plurality of rolling elements held between an inner race and an outer race with a cage interposed therebetween, wherein an ~~the~~ oil film of lubricating oil of which the dynamic viscosity at 40°C is 20 to 150 mm^2/s is formed on the raceway surfaces of the inner and outer races, the cage and the rolling elements, and grease is enclosed.

When the dynamic viscosity of the lubricating oil at 40°C is less than 20 mm^2/s, the strength of the oil film is low and fretting corrosion is liable to be created by extraneous vibrations. When conversely, the dynamic viscosity at 40°C is higher than 150 mm^2/s, rotation torque increases because the dynamic viscosity of the lubricating oil is high. Further, to reduce fretting corrosion, it is preferable that the dynamic viscosity at 40°C be 40 mm^2/s or greater.

While the lubricant composition used as the lubricating oil is not particularly limited, it may be composed of base oil and various additives mentioned below, whereby there is formed lubricating oil film having a fretting-resisting property and a rust prevention property and suitable for use at a high temperatures and high speeds. In the embodiments as described hereinafter, the composition of the additives

can be selected in accordance with use ~~using~~ conditions of the bearings if control of fretting corrosion is maintained, and ~~functions of~~ anti-rust properties and additional properties can also be provided ~~be combined in need~~. Particularly, if the higher anti-rust properties are required under some ~~using~~ use conditions, preferably the lubricant oil may be anti-rust lubricant oil containing a ~~combined with the~~ rust prevention agent which has high anti-rust properties.

(Base Oil)

Regarding the base oil, as ester oil, use may preferably be made of diester oil obtained from the reaction of dibasic acid and branch alcohol, aromatic ester oil obtained from the reaction of aromatic tribasic acid and branch alcohol, or hindered ester oil obtained from the reaction of polyatomic alcohol and monobasic acid.

As diester oil, mention may be made of dioctyl adipate (DOA), diisobutyl adipate (DIBA), dibutyl adipate (DBA), dioctyl azelate (DOZ), dibutyl sebacate (DBA), dioctyl sebacate (DOS), methyl acetyl recinolate (MAR-N) or the like.

As aromatic ester oil, mention may be made of trimellitic acid ester, trioctyl trimellitate (TOTM), tridecyl trimellitate, tetraoctyl pyromellitate or the like.

As hindered ester oil, mention may be made of one obtained by polyatomic alcohol and monobasic acid ~~shown.~~

~~below~~ being suitably reacted with each other. Monobasic acid to be reacted with polyatomic alcohol may be single or plural. Further, it may be used as complex ester which is oligoester of polyatomic alcohol and mixed aliphatic acid of dibasic acid and monobasic acid.

As polyatomic alcohol, mention may be made of trimethylol propane (TMP), pentaerythritol (PE), dipentaerythritol (DPE), neopentyl glycol (NPG), 2-methyl-2-propyl-1,3-propane (MPPD) or the like.

As monobasic acid, use is made chiefly of univalent aliphatic acid of C_4 to C_{18}. Specifically, mention may be made of acetic acid, valerianic acid, caproic acid, caprylic acid, enanthic acid, pelargonic acid, capric acid, undecanic acid, laurylic acid, mistiric acid, palmitic acid, beef fatty acid, stearic acid, caproleic acid, undecylenic acid, linder acid, tudu acid, fiseterinic acid, milistolenic acid, palmitoleic acid, petroserine acid, oleic acid, elaiolic acid, asclepic acid, vaccenic acid, sorbic acid, linoleic acid, linolenic acid, sabineic acid, recinoleic acid, or the like.

As synthetic hydrocarbon oil, there is phenyl ether oil in which (di)alkyl chain of C_{12} to C_{20} of disphenyl, tripheyl and tetraphenyl was derived.

Taking lower evaporation and longer life into account, it is preferable that ester oil be chosen from

aromatic ester oil and hindered ester oil and be used singly or mixedly. Particularly TOTM is readily available and is excellent in a low evaporating property, a lubricating property, etc. Also, (di)alkyl polyphenyl ether oil is preferable as ether oil. Fluorophosphazene oil can also be suitably used.

Also, by adding additives such as rust prevention agents, oily agents and oxidation preventing agents mentioned below, lubricating performance (fretting-resisting property or the like) and durability ~~durable performance~~ can be enhanced ~~more improved~~.

(Rust Prevention ~~prevention~~ Agent)

Organic sulfonic acid metal or ester is preferable as a rust prevention agent. As organic sulfonic acid salt, use is made, for example, of dinonyl naphthalene sulfonic acid and heavy alkyl benzene sulfonic acid, and as the metal salt thereof, there is calcium sulfonate, barium sulfonate, sodium sulfonate or the like.

As ester, in sorbitan derivative, there is sorbitan monolaurate, sorbitan tristearate, sorbitan monooleate, sorbitan trioleate or the like as the partial ester of polybasic carboxylic acid and polyatomic alcohol. As alkyl ester type, there is polyoxyethylene laurate, polyoxyethylene oleate, polyoxyethylene stearate or the like.

As these rust prevention agents, organic sulfonic

acid metal salt and ester can be used singly or as a mixture. Taking it into account to improve the rust prevention property and suppress fretting corrosion, ester polyoxyethylene sorbitan laurate is high in dissolving property and is suitably used as sulfonic acid metallic salt such as calcium sulfonate, and fluorophosphazene oil.

(Oily Agent)

As an ~~oil~~ oily agent, oleic acid, stearic acid or the like as higher fatty acid, lauryl alcohol, oleyl alcohol or the like as higher alcohol, stearyl amine, cetyl amine or the like as amine. ~~these~~ These can be used singly or mixedly.

(Oxidation Preventing Agent)

As an oxidation preventing agent, a nitrogen containing compound oxidation preventing agent and a phenol oxidation preventing agent may preferably be used singly or as a mixture.

As the nitrogen containing compound oxidation preventing agent, there is phenyl α naphthylamine, diphenylamine, phenylene diamine, oleyl amideamine, phenothiazine or the like.

As a phenol oxidation preventing agent, there is hindered phenol such as p-t-butyl-phenyl salicylate, 2,6-di-t-butyl-p-phenyl phenol, 2,2'-methylenebis-(4-methyl-6-t-octyl phenol), 4,4'-butyrydenbis-6-t-butyl-m-cresol, tetrakis[methylene-3-(3',5'-di-t-butyl-

4'-hydroxyphenyl)propionate]methane, 1,3,5-trimethyl-2,4,6-tris(3,5-di-t-butyl-4-hydroxylbenzil)benzene, n-octadecyl-β-(4'-hydroxy-3',5'-di-t-butylphenyl)propionate, 2-n-octylthio-4,6-di(4'-hydroxy-3',5'-di-t-butyl)phenoxy-1,3,5-triazine, 4,4'-thiobisu-[6-t-butyl-m-cresol], 2-(2'-hydroxy-3'-t-butyl-5'-methylphenyl)-5-chlorobenzotriazole or the like.

(Extreme Pressure Agent)

As an extreme pressure agent, use can be made of organic metallic salt such as molybdenum thiocarbamate, molybdenum dithio phosphate, zinc diocarbamate, zinc dithiophosphate or the like.

(Corrosion Preventing Agent)

As a corrosion preventing agent, mention may be made of phosphoric acid ester, phosphorous acid ester or the like. Particularly, molybdenum dithiocarbamate and phosphorous acid ester exhibit an excellent ~~effect in the~~ fretting resisting property and ~~can~~ may therefore be ~~suitably used~~ preferred.

In addition to the foregoing agents, a friction preventing agent, a viscosity index improving agent or the like may be contained in the lubricating oil. These may all be conventional agents.

Regarding the base oil and additive of the grease enclosed in the above-described fretting-resisting roller bearing of the present invention, use may be

made of ones similar to the above-described lubricating oil composition of the present invention. Also, a thickness regulating agent may be a conventional one such as metallic soap or urea resin, but from the viewpoint of the characteristic of the bearing for a spindle, lithium soap having an excellent characteristic in acoustic life is preferable.

In the case of the fretting-resisting roller bearing of the present invention, the contacting portions of the raceway surfaces of the outer and inner races and the rolling elements are the same material or different materials. ~~and~~ Preferably, when different materials are used, they are steel and ceramics or steel and a super-hard alloy. If the lubricating oil in the present invention is used, the fretting corrosion will be greatly mitigated, and further, under an environment of severe vibration condition, different materials may be small in the frictional force acting on the contacting portions as compared with steel and steel, and in these contacting portions, it is more difficult for such an injury which will lead to fretting corrosion to occur.

In the case of ceramics, the material forming the rolling elements may be silicon nitride, zirconia, alumina or the like, and in the case of a super-~~high~~ hard alloy, the material forming the rolling elements may be tungsten carbide or the like.

The friction characteristic on the contacting

portions of the raceways of the outer and inner races made of steel and the rolling surfaces of the rolling elements made of ceramics or a super-hard alloy is improved as compared with the friction characteristic when steel and steel contact with each other~~, even if the combination of different materials is steel and ceramics or steel and a super-hard alloy~~. Above all, the combination of bearing steel and silicon nitride, stainless steel and silicon nitride, bearing steel and zirconia, bearing steel and tungsten carbamate, or stainless steel and tungsten carbamate provides an excellent friction characteristic (a low friction characteristic) and is excellent in the fretting resisting property. By combining these with the above-mentioned lubricating oil, a further effect is obtained against fretting corrosion and these combinations can be preferably be used.

Description will now be made of the conditions and results of evaluation tests carried out to confirm the effect of the present invention.

[Bearing Outer Race Swing Test]

Tested bearing	:	695
Frequency	:	27 Hz
Angle of swing	:	2°
Load (Fa)	:	14.7 N
Frequency of swing	:	1×10^5 times
Enclosed grease	:	Lithium soap grease

The above-mentioned swing test was carried out, and the acceleration of the bearing in the radial direction thereof after the test was measured and evaluation was effected.

A heretofore used bearing specification [Comparative Example 1] was subjected to a swing test, and comparison evaluation was effected with the bearing radial direction acceleration signal execution value after the test being 100%.

Because ~~It is because~~ the traces of minute fretting corrosion created on the inner and outer races and rolling elements of the bearing can be measured with good sensitivity, ~~that~~ the bearing radial direction acceleration was used as a test evaluation item.

[Measurement of Rotation Torque]

Tested bearing	:	695
Load (Fa)	:	14.7 N
Number of revolutions	:	3600 rpm

As regards the magnitude of torque, 1.2 gf·cm or less was regarded as being successful.

The test conditions of each embodiment and each comparative example are as follows:

[Embodiment 1]

A bearing in which lubricating oil C of which the dynamic viscosity at 40°C was 90 mm^2/s was formed into film on the raceway surfaces of inner and outer races, a cage and rolling elements and grease was enclosed was

tested in a pre-load state under the above-mentioned conditions.

[Embodiment 2]

A bearing in which rolling elements were made of silicon nitride and lubricating oil C of which the dynamic viscosity at 40°C was 90 mm^2/s was formed into film on the raceway surfaces of inner and outer races, a cage and rolling elements and grease was enclosed was tested in a pre-load state under the above-mentioned conditions.

[Embodiment 3]

A bearing in which rolling elements were made of tungsten carbide of Vickers hardness 1300 and lubricating oil C of which the dynamic viscosity at 40°C was 90 mm^2/s was formed into film on the raceway surfaces of inner and outer races, a cage and rolling elements and grease was enclosed was tested in a pre-load state under the above-mentioned conditions.

[Embodiment 4]

A bearing in which lubricating oil B of which the dynamic viscosity at 40°C was 25 mm^2/s was formed into film on the raceway surfaces of inner and outer races, a cage and rolling elements and grease was enclosed was tested in a pre-load state under the above-mentioned conditions.

[Embodiment 5]

A bearing in which rolling elements were made of

silicon nitride and lubricating oil B of which the dynamic viscosity at 40°C was 25 mm^2/s was formed into film on the raceway surfaces of inner and outer races, a cage and rolling elements and grease was enclosed was tested in a pre-load state under the above-mentioned conditions.

[Embodiment 6]

A bearing in which rolling elements were made of tungsten carbide of Vickers hardness 1300 and lubricating oil B of which the dynamic viscosity at 40°C was 25 mm^2/s was formed into film on the raceway surfaces of inner and outer races, a cage and rolling elements and grease was enclosed was tested in a pre-load state under the above-mentioned conditions.

[Embodiment 7]

A bearing in which lubricating oil E of which the dynamic viscosity at 40°C was 150 mm^2/s was formed into film on the raceway surfaces of inner and outer races, a cage and rolling elements and grease was enclosed was tested in a pre-load state under the above-mentioned conditions.

[Embodiment 8]

A bearing in which lubricating oil F of which the dynamic viscosity at 40°C was 25 mm^2/s was formed into film on the raceway surfaces of inner and outer races, a cage and rolling elements and grease was enclosed was tested in a pre-load state under the

above-mentioned conditions.

[Embodiment 9]

A bearing in which lubricating oil G of which the dynamic viscosity at 40°C was 90 mm^2/s was formed into film on the raceway surfaces of inner and outer races, a cage and rolling elements and grease was enclosed was tested in a pre-load state under the above-mentioned conditions.

[Embodiment 10]

A bearing in which lubricating oil H of which the dynamic viscosity at 40°C was 120 mm^2/s was formed into film on the raceway surfaces of inner and outer races, a cage and rolling elements and grease was enclosed was tested in a pre-load state under the above-mentioned conditions.

[Comparative Example 1]

A bearing in which lubricating oil A of which the dynamic viscosity at 40°C was 11 mm^2/s was formed into film on the raceway surfaces of inner and outer races, a cage and rolling elements and grease was enclosed was tested in a pre-load state under the above-mentioned conditions.

[Comparative Example 2]

A bearing in which lubricating oil D of which the dynamic viscosity at 40°C was 160 mm^2/s was formed into film on the raceway surfaces of inner and outer races, a cage and rolling elements and grease was enclosed was

tested in a pre-load state under the above-mentioned conditions.

The compositions of the lubricating oils A to H used in the above-described embodiments and comparative examples are shown in Table 1 below.

Table 1

	Lubricating Oil A	Lubricating Oil B	Lubricating Oil C	Lubricating Oil D
kind of oil	DOS	PAO	TOTM	ADE
dynamic viscosity mm^2/s (40°C)	11	25	90	160
rust prevention agent	calcium sulfonate	calcium sulfonate	calcium sulfonate	sodium sulfonate
additive	–	zinc dithiophosphate	molybdenum dithiophosphate	phosphorous acid ester

Table 1 (continued)

	Lubricating Oil E	Lubricating Oil F	Lubricating Oil G	Lubricating Oil H
kind of oil	MO	PET	TOTM	PAO
dynamic viscosity mm^2/s (40°C)	150	25	90	120
rust prevention agent	sodium sulfonate	calcium sulfonate	barium sulfonate	calcium sulfonate
additive	phosphorous acid	phosphorous acid ester	zinc dithiophosphate	molybenum dithiophosphate

DOS : dioctyl sebacate,

PAO : poly-α-olefin,

TOTM : trioctyl trimellitate,

ADE : alkyl diphenyl ether

MO : mineral oil

The acceleration signal execution values and rotation torques in the above-described embodiments and comparative examples are shown in the graphs of Figs. 1 and 2, respectively.

According to the fretting-resisting roller bearing of the present invention described above, there are obtained the following effects:

(1) The oil film of lubricating oil having high dynamic viscosity is formed on the raceway surfaces of the inner and outer races, the cage and the rolling elements and therefore, there can be provided a

fretting-resisting roller bearing in which the strength of the oil film is high, ~~and~~ the fretting-resisting property during conveyance is improved and ~~also~~ the various characteristics of the bearing are not adversely affected, and which further achieves a higher temperature and a higher speed as well as a longer life.

(2) When the material of the rolling elements is ceramics or a super-hard alloy of Vickers hardness 1300 or greater and the outer and inner races are made of steel and a material differing from the material of the outer and inner races is used as the material of the rolling elements, the hardness thereof is increased, whereby not only fretting corrosion can be suppressed by the prevention of the adhesion phenomenon between the members (the raceway surfaces of the outer and inner races and the rolling elements) and the decrease in the Hertzian contact area by the difference in Young's modulus, but also the bearing functions well even under the use conditions of high temperatures and high-speed rotation.